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DIRECTIONS FOR MODERNISATION AND CONSTRUCTION OF CONTEMPORARY RAIL VEHICLES

KIERUNKI MODERNIZACJI I BUDOWY WSPÓŁCZESNYCH POJAZDÓW SZYNOWYCH

A b s t r a c t

This article presents brief characteristics of rail vehicles modernised or produced by NEWAG S.A. The article discusses currently produced and modernised Electric Multiple Units (EMUs) and Diesel Multiple Units (DMUs) as well as diesel locomotives undergoing a modernisation process. Based on the presented characteristics, the rail vehicle modernisation and construction process trends prevailing in the contemporary railway market were brought closer to the reader.

Keywords: *rail vehicle*, *modernisation*, *modernisation*, *locomotive*, *Electric Multiple Unit*

S t r e s z c z e n i e

W niniejszym artykule przedstawiono krótką charakterystykę pojazdów szynowych modernizowanych lub produkowanych w firmie NEWAG S.A. Omówiono obecnie produkowane i modernizowane elektryczne i spalinowe zespoły trakcyjne oraz modernizowane lokomotywy spalinowe. Na podstawie tej charakterystyki przybliżono trendy w modernizacji i budowie pojazdów szynowych, jakie obowiązują na współczesnym rynku kolejowym.

Słowa kluczowe: *pojazd szynowy*, *modernizacja*, *lokomotywa*, *elektryczny zespół trakcyjny*

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1. Introduction

In recent years, rail transport has been developing dynamically and new railway operators have emerged on the market. This new competitive scenario is compelling carriers to compete with one another. One of the ways of building a competitive advantage is to have modern rolling stock.

Rail vehicles used for passenger transport should be renowned for their great reliability, high levels of safety, superior comfort for passengers as well as by low operational costs. The locomotives are principally expected to consume less energy, offer better working conditions for the engine driver and to improve the traction properties of the train. Additionally, all vehicles have to comply with the requirements set forth in various items of domestic and international legislation.

NEWAG S.A. is one of the companies dealing with the modernisation of existing rolling stock and production of new units, having all of the aforementioned features.

2. Electric Multiple Units (EMUs)

For several years now, the Company has been upgrading EN57 and EN71 electric multiple units (EMUs). As a result of the first major overhaul, which comprised the replacement of rail-car bodies and traction systems, two new types of vehicles were created. These are called 14WE (Fig. 1) and 14WE-P.

From the original electric multiple unit, only the bogie frame, frame elements and bogies were kept and were subjected to a major overhaul. The retrofitted vehicles were adapted for handling suburban commuter traffic. To enhance operational comfort, the traction system was retrofitted in accordance with documentation drawn up by the 'ROLLING STOCK' Rail Vehicle Institute. The traction system consists of two bogies: 36AN rolling bogie and 23MN motor bogie. The modernisation process involved the changing of the method of springing wheel sets. The multiple plate springs and leaf springs were replaced with cone springs as well as metal and rubber springs, which improved travelling comfort to a large extent. At the same time, the wheel set driving was changed by means of the introduction of a new type of axle-boxes with bearings marked NJ + NJP 130 [1].

Fig. 1. 14WE Electric Multiple Unit (EMU)

The scope of other modernisation projects of the EN57 and EN71 electric multiple units (EMUs) comprises mainly the change of external appearance, enhancement of travelling comfort through improvement of the EMU interior and installation of equipment enabling the disabled to use the trains. An example of such a retrofitted Electric Multiple Unit (EMU) is presented in Figure 2.

Fig. 2. EN71 Electric Multiple Unit (EMU) with modernized front (Photo by G. Motyka)

The design of the engine driver's cabin was modified by making a new steel frame incorporated into the remaining part of the vehicle. To the frame, a self-supporting front made of polyester and glass laminate was added using special adhesive. At the front, the heated wrap-around window was incorporated using a special adhesive.

In the car, a toilet cubicle was added. It is suitable for use by the disabled. To this car, folding ramps were added that enable the disabled to embark and disembark from the train. Additionally, the rack system was added to enable the carrying of six bicycles in a vertical position.

In the motor car, three second class compartments were separated, divided by two vestibules. In the upgraded vehicles, the partition walls and sliding door were removed and in their place, windscreens were installed.

The engine driver's cab was modernized in the EMU. Thanks to the relocation of partition walls, the engine driver's cabin was enlarged. It is now equipped with new, ergonomic seats for the engine driver and assistant driver enabling quick evacuation.

The previously applied pneumatic windscreen wipers were replaced with electric windscreen wipers with washers. To improve visibility in harsh weather conditions, a heated windshield and new sun visor were installed.

The engine driver's console was modernized in accordance with current effective standards. In addition to standard keys and indicators the console also contains a multiprocessor, which displays operational parameters when the train is on the move. Figure 3 shows the modernized engine driver's console in EN57 and EN71 Electric Multiple Units (EMUs).

The retrofitted EN57 and EN71 Electric Multiple Units (EMUs) are equipped with internal and external surveillance systems. The internal surveillance system enables recording of events onboard the train and is performed using television cameras, the picture is displayed on two 17" monitors [2]. The external surveillance system ensures good visibility of all areas next to each side of the train, which in fact replaces the conventional mirrors.

Fig. 3. A view of the console in EN57 and EN71 Electric Multiple Units (Photo by G. Motyka)

In the retrofitted EMUs, the same bogies were installed as in the 14WE train sets. To propel EMUs, asynchronous motors were applied and thus the combined driving system was created together with a two-shift final drive.

The first Electrical Multiple Unit (EMU) built by NEWAG S.A. from scratch is 19WE (Fig. 4).

Initially, the 19WE Electric Multiple Units were designed to go to a maximum speed of 130 km/h. Now these vehicles can be operated at a speed of 160 km/h. Because of the interior layout, the EMU has been designed to handle local high density passenger traffic. The basic arrangement of the EMU is "s+d+d+s" (motor car + trailer car + trailer car + motor car). In case of high traffic density, the EMU can be operated using multiple traction. In order to perform the fast coupling of units, automatic self-acting couplers made by Voith were applied.

Fig. 4. 19WE Electric Multiple Unit (EMU)

The interior of the 19WE Electric Multiple Unit was arranged in such a way as to achieve the highest possible number of passenger seats. Therefore twin seats were installed using row and opposite layouts (2+2), otherwise the seats were installed using the "metro" layout. Thanks to such a layout, the EMU seating capacity is 183 seats and the total number of standing places is 702, assuming 5 people per m^2 and 1222 standing places assuming that per m^2 there will be 10 persons [3].

The 19WE Electric Multiple Unit has been adapted to carry the disabled. In the motor cars, a space has been designated for mounting two wheelchairs. The disabled may access the EMU using lifts or platforms, depending on the ordered version. The floor height above the rail head level is 1160 mm.

The EMU has been equipped with a multimedia system. It offers the possibility to broadcast audio-video signals throughout the train which is activated automatically. The system consists of among others, two 17" display monitors in a vandal-proof casing. The passengers' safety is assured by an internal and external surveillance system.

To enable the EMU to drive at 160 km/h, an additional place was added for the assistant driver in the engine driver's cabin, which consists of a second seat and an additional console. The additional console for the assistant driver comprises: a dead-man's handle; warning horn manipulator; emergency brake; seat movement control button.

The 19WE Electric Multiple Units (EMUs) are equipped with rolling bogies of the 70RSTa type and driving bogies of 70RSNa type. These bogies comply with the safety requirements for driving with faulty springs of the second degree, with a maximum speed of 60 km/h. The bogies are equipped with a two-level springing system. The first level of springing consists of four concentric double-coil springs mounted in equalizers' guides. The second level of springing consists of two pneumatic springs made by PHOENIX.

The second newly built Electric Multiple Unit is 35WE called "Impulse" (Fig. 5). The 35WE Electric Multiple Unit has been designed for handling high density local traffic. The train consists of six cars with the following arrangement: "s+d+s+s+d+s" (motor car + trailer car + motor car + motor car + trailer car + motor car). The 35WE Electric Multiple Unit, like the previous EMU, has been designed to travel at a maximum speed of 160 km/h. The Electric Multiple Unit has been designed to carry the disabled. The disabled wheelchair passengers may access the train through platforms mounted on both sides of terminal units.

Fig. 5. 35WE Electric Multiple Unit (EMU) (Photo by Ł. Mikołajczyk)

In the passenger area, between doors of the units there are double seats facing forward or backward with an appropriate aisle width ensuring comfortable access for passengers. In the section designed for large baggage (A and F train units), including bicycles, the seats are hinged and installed according to 'metro' spatial layout. In these train units, space for wheelchairs has also been designed – there are hooks for fixing wheelchairs. The floor height above rail head level in the entrance zone is 760 mm for train units equipped with a toilet cubicle, whereas for the train units without a toilet cubicle, the floor height above rail head level is 850 mm [4].

Because the EMU has been designed to run at 160 km/h, in compliance with the current legislation, the engine driver's cabin is equipped with two driver's seats. One is for the engine driver, the other one for the assistant driver. The seats have been mounted in a manner such as to allow for quick evacuation.

The 35WE Electric Multiple Units are equipped with electronic energy meter called the LE3000plus. The LE 3000plus energy meter is a modern device for settlement purposes supporting metering of the power and traction energy in the direct current (DC) Electric Multiple Units. Thanks to the built-in GSM modem, it is possible to transmit metering data remotely and automatically to the settlement systems.

The 35WE Electric Multiple Unit, similarly to the trains described above, has a built-in surveillance system to ensure a safe journey for passengers and also has a public address system to provide information for the passengers.

The 35WE Electric Multiple Unit is based on four, biaxial 70RSNd driving bogies and four, biaxial 72RSTd rolling bogies of the Jacobs type.

The 35WE Electric Multiple Unit is powered by eight asynchronous electric motors with a total power of 3200kW, coupled with axial transmissions mounted on four driving bogies.

The most modern Electric Multiple Unit produced by NEWAG S.A. is the 31WE (Fig. 6). The 31WE and 35WE Electric Multiple Units differ in the number of units, traction system and driving system.

The train consists of four units in the Bo2'2'2'Bo configuration (motor car + trailer car + trailer car + motor car).

Fig. 6. 31WE Electric Multiple Unit (EMU)

The 31WE Electric Multiple Unit is based on two, biaxial 70RSNc driving bogies and three, biaxial 72RSTc rolling bogies of Jacobs type.

The 31WE Electric Multiple Unit is powered by four asynchronous electric motors with a total power of 500 kW, coupled with DOSTO-GETRIEBE axial transmissions mounted on two driving bogies [5].

The 31WE Electric Multiple Unit has been designed to run at a maximum speed of 160 km/h. During official certification tests carried out by the Railway Engineering

Institute in February of this year, the EMU reached the speed of 211.6 km/h. The tests were carried out on a section of central trunk line, between Psary and GóraWłodowska. The in--test and after-test performance of all devices was correct.

The fittings of both EMUs and the engine driver's cabin are pretty much the same. Differences may occur due to EMU customization for specific users. Figure 7 shows samples of interior layouts of 19WE, 35WE and 31WE Electric Multiple Units. Figure 7a shows a view of the compartment with double mounted seats, whereas Figure 7b shows a train unit with a ticket machine installed, Figure 7c shows a compartment with seats mounted according to the "metro" spatial layout, whereas Figure 7d shows a compartment with seats for the disabled.

Fig. 7. Examples of interiors of Electric Multiple Units (Photo by Ł. Mikołajczyk)

3. Diesel Multiple Units (DMUs)

Some of the Diesel Multiple Units that comply with all required standards and regulations as well as the expectations of rail vehicle users are DMUs marked 220M and 221M (Fig. 8).

The major difference between the two DMUs is the different number of train units. The 220M Diesel Multiple Unit is a two-unit vehicle, whereas 221M DMU is a three-unit train. Diesel Multiple Units have been designed for passenger transport on local lines with high traffic flows, especially on non-electrified railway lines.

The basic arrangement of the 220M DMU is “s+s” (motor car + motor car), whereas for the 221M DMU – “s+d+s” (motor car + trailer car + motor car). Both DMUs, depending on operational requirements, may be operated in multiple traction mode.

In both DMUs, 74RSNa driving bogies and 72RSTa rolling bogies have been used. To power 220M DMU, the PowerPack propulsion by MTU was used. It consists of a diesel motor of type 6H1800R85L and ZF-EcoLife Rail transmission. To power 221M DMU, the PowerPack propulsion by MTU was used. It consists of a diesel motor of type 6H1800R84 and hydrodynamic transmission of type ZF [6, 7].

The two-unit DMU has two motors, one motor in each train unit, whereas in the three-unit DMU, the propulsion systems are mounted in each drive unit of the DMU.

Both DMUs may be operated at a maximum speed of 120 km/h.

Fig. 8. 220M and 221 M Diesel Multiple Unit (DMU) (Photo by Ł. Mikołajczyk, G. Motyka)

A part of the passenger compartment (Fig. 9) has been lowered, and in that part the unit has been adapted for carrying wheelchair passengers, passengers with large luggage and for carrying bicycles and skis fixed in special holders. Additionally, in the low floor car, a toilet cubicle, operated in a closed loop system, has been fitted. It has also been adapted for use by the disabled.

To enable boarding and deboarding for the disabled, the DMUs have been equipped with lifts.

Fig. 9. Passenger compartment of Diesel Multiple Units (Photo by Ł. Mikołajczyk)

The Diesel Multiple Units have been equipped with, among others, a public address system, internal and external surveillance systems, operational data recorder, passenger counting system and a public address system. To ensure the safety of people in the passenger compartment, the DMUs have been equipped with panic buttons, and also electrical sockets which will make it possible to plug in a portable computer or a mobile phone.

All DMU doors are automatically closed when the DMU exceeds the threshold speed of 5 km/h.

The engine driver's cabin has been designed with the prime intention of providing very good working conditions for the engine driver. The cabin design enables the engine driver to observe both sides of the train and allows for fast and easy evacuation. The engine driver's cabin is equipped with external mirrors, heated and adjusted from the inside with the option of folding them while the train is on the move and once the journey has been completed.

4. Diesel locomotives

NEWAG S.A. upgrades locomotives to help to comply with the prevailing current requirements in the railway market. Examples of such upgrading projects include diesel locomotives of 6Dg/B, 15D or 16D types.

The diesel locomotive of 6Dg/B type (Fig. 10) is an example of a complete upgrading of the shunting diesel locomotive SM42. The scope of upgrading included, but was not limited to: a change of the locomotive's external appearance; improvement of engine driver work ergonomics; replacement of the driving unit. The retrofitted locomotive still has the same traction system, which employs 1LN bogies.

Fig. 10. The diesel engine of 6Dg/B type

The locomotive now has a modern shape. During the modernisation process, the height of the engine rooms was reduced by approximately 300 mm (compared to the previous solution), which greatly improved visibility from the engine driver's cabin.

The working conditions of the engine driver were also improved thanks to the application of an air conditioning system. A modern KL20E air conditioning unit made by Konvekta with a cooling capacity of 4.3 kW has been installed in the locomotives. The air conditioning units use an environmentally-friendly coolant R134a. Additionally, under each console, a Zephyr 3D water heating system by Webasto was installed. The water heating system is a part of the water cycle of the diesel motor C27. In the locomotives, the installation of a mechanical tachograph with registration on paper tape was abandoned. Instead, a modern electronic tachograph TELOC 1500 by HaslerRail was installed. It registers operational parameters on digital storage cassettes (EKP).

During the modernisation process, a brand new design for the engine driver's cabin was developed (Fig. 11). The cabin width was enhanced. The side walls were equipped with modern sliding plug windows with internally bonded window panes. The windshields were also constructed using internal bonding technology, and the panes are equipped with on electric heating system with a total power of 770 W [8].

Fig. 11. Engine driver's cabin in the locomotive 6Dg/B (Photo by Ł. Mikołajczyk)

In the cabin, there are two ergonomic engine driver's consoles. To enhance the working comfort of the engine driver for each console, ergonomic seats, made by Grammer, were installed. The seats have a profiled backrest and allow for adjustment to match the anthropometric features of the engine driver (adjustment of armrest, seat height), additionally they are equipped with vibration dampers. The engine driver's seat design allows for a 180-degree turn.

The engine driver's cabin has been mounted on the frame by means of four metal and rubber elements without metallic (rigid) connections with other parts of the locomotive. This ensures the maximum reduction of vibrations transferred to the cabin structure.

The diesel engine a8c22 was replaced with a new 12-cylinder, V-engine with microprocessor controlled fuel injection, turbocharged by means of two turbochargers made by Caterpillar from C27 ACERT (DITA) series. The engines from that series meet the most stringent exhaust-gas emission standards according to EU Directive 2004/26 EC (they comply with the STAGE IIIA exhaust-gas emission standards) with the total output of 708 kW.

The driving unit consists of the aforementioned diesel engine and main synchronous generator of Ghp 400 M4C type and auxiliary synchronous generator of Ghp 315 S4K type. The main generator is connected directly with the engine crankshaft by means of a flexible shaft coupling of CM8000 type. The 6Dg/B locomotives are equipped with devices enabling a precise measurement of used fuel. The fuel consumption measurement system has been designed for monitoring, registration and transfer in real time of operational data including vehicle location and information about fuel volume in the tanks and information about fuel consumption by the locomotive's diesel engine in particular.

As a result of the modernisation of the SM48 diesel locomotive, two types of diesel locomotive were obtained: 15D and 16D (Fig. 12). The 15D locomotive has been designed for operation using regular gauge track, whereas the 16D locomotive has been designed for the operation on broad-gauge track with a gauge of 1520 mm.

The modernisation process included but was not limited to the modification of the locomotive appearance to give it a modern look, adaptation of the driver's cabin to the current prevailing standards and replacement of driving unit. The bogies were not upgraded, only necessary repairs were performed.

During the modernisation the project, the height of engine rooms was reduced, which greatly improved visibility from the engine driver's cabin.

Fig. 12. 15D/16D diesel locomotives (Photo by Ł. Mikołajczyk)

The cabin design enables the engine driver to observe each side of the train set and allows for easy and fast evacuation. The modernized consoles allow for fast and easy operation. The drivers' seats are based on a metal frame, made of bent tubes and sections and allow for fast evacuation. Additionally, the seats may be adjusted longitudinally and vertically. Additionally, to improve the working comfort for the engine driver, the seat has a mechanical system of damping vibrations felt during train running, with the selection of body weight of the seating person. The ergonomic finish of the seat is supplemented with the adjustable headrest and two adjustable folding armrests.

In the locomotives air, conditioning unit was installed in the engine driver's cabin, which uses an environment-friendly coolant R134a.

The driving unit consists of a 3512C diesel engine with the power of 1480 kW, main generator Glp 500 L4 made by EMIT S.A and auxiliary generator Ghp 315 M4K. The main generator is connected directly with the 3512C engine crankshaft by means of flexible shaft coupling. 3512C diesel engine made by Caterpillar complies with UIC exhaust gas emission standard STAGE IIIA.

The locomotive is equipped with a fuel consumption control system, which enables the determining of the location of the rail vehicle and the transferring of information about quantity of fuel left in the tanks or information about fuel consumption by the locomotive's diesel engine. The locomotives were equipped with ED118A traction engines. The ED118A traction engine has been designed to convert electric energy generated by the main generator into mechanical energy of rotary motion. The original Russian engines were subjected to a major overhaul and additionally, the engine insulation was upgraded to H class [9].

The locomotives are equipped with a surveillance system. The surveillance system allows for, among other things, the ability to watch the railway line in front of the vehicle. Additionally, it is equipped with such functionalities as live video display, search and playback of any piece of video according to date/time or event and remote surveillance of the locomotive via Internet using a personal computer (PC).

Some locomotives are also equipped with a radio control system. The components of the system are shown in Figure 13.

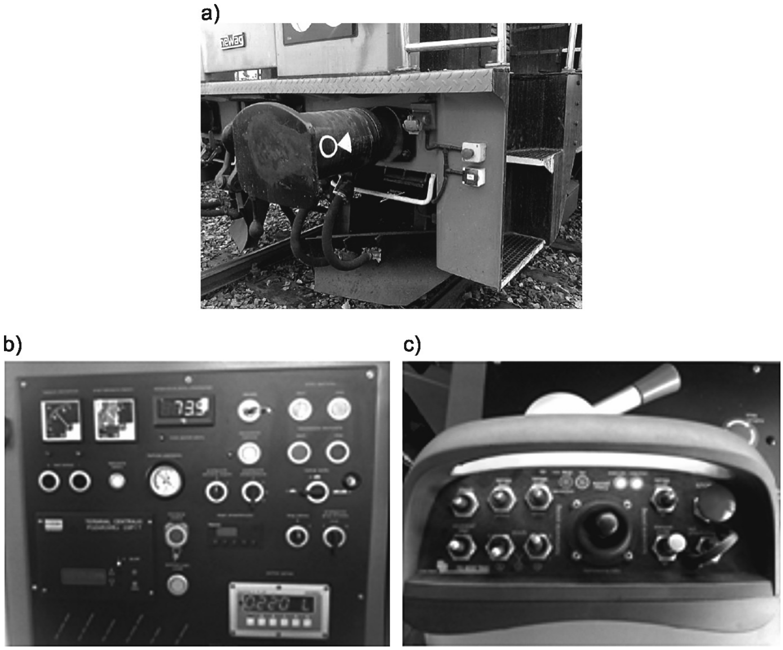

Fig. 13. Locomotive radio control system components

The locomotive control system allows for its control from the outside of the engine driver's cabin. The locomotive is equipped with emergency braking push-button (Fig. 13a), on the console there is a panel (Fig. 13b) that enables the switching of the locomotive over to radio control mode. The control is exercised using a joystick (Fig. 13c).

5. Closing Remarks

Based on brief characteristics of the presented vehicles, produced by NEWAG S.A., it can be remarked that the directions of modernisation and construction of rail vehicles include mainly the change of vehicle appearance, improvement of working conditions for the engine driver, enhancement of travelling comfort for the passengers, mounting of new driving units and traction systems, which will allow for the reduction of operating costs, among other things.

The modification of vehicle appearance is designed to make the vehicle look modern and have streamlined shape to reduce aerodynamic drag, which in turn will make it possible to reduce energy consumption.

The modernisation of the engine driver's cabin, both in Electric Multiple Units (EMU) and Diesel Multiple Units (DMU), comprises widening of the cabin and installation of ergonomic consoles and seats adapted to the driver's figure.

To improve the working environment for the engine driver, television cameras are installed to replace conventional mirrors. Consequently, the engine driver has a better view of things happening around the vehicle.

The modernisation and construction directions for the passenger compartments include primarily making the trains accessible for the disabled. For the wheelchair passengers space is isolated onboard the train where the disabled can embark and disembark the vehicle without any problem and they can travel safely. Additionally, the train units are equipped with audio-visual systems that enable deaf or blind people to learn about the current situation onboard the train. Additionally, multiple units are equipped with bicycle racks, which enable the transport of bicycles or skis.

To further enhance travelling comfort onboard the train, ticket or vending machines will be installed to enable travellers to buy tickets, various snacks or soft drinks.

The vehicles are equipped with a surveillance system, which registers developments onboard the train, which gives a feeling of safety to the passengers.

The modernised and brand new passenger cars are equipped with modern train running systems, which enhance travelling comfort due to the application of pneumatic cushions.

The rebuilt locomotives are equipped with environmentally-friendly diesel engines that significantly reduce the air emissions of exhaust gases and consume less fuel. Additionally, fuel consumption metering systems are installed.

Moreover, all vehicles are equipped with an air-conditioning system which improves travelling comfort for the passengers and working comfort for the engine driver.

The new vehicles should be equipped with systems and subassemblies enabling them to exceed speeds of 160 km/h, which in turn will make it possible to reduce the journey duration, thus enabling passengers to save time.

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